UNIT 1 - ENERGY
SECTION 1 - ENERGEIA

Vocabulary

atom	gamma rays	nuclear energy
chemical energy	hydrogen	potential energy
compound	infrared	radio wave
electrical energy	kinetic	thermal energy
electricity	law of conservation of energy	ultraviolet
electromagnetic radiation	light energy	uranium
electron	luminescence	visible light
energy	mass	wavelength
energy conversion	matter	work
exothermic reaction	mechanical energy	x-ray
friction	molecule	

Energeia is the Greek word for **energy**, meaning in or at work. Over time, energy has come to mean many things to us. In physical science, energy means the ability to do work. Work means a change in position, speed, state, or form of matter. Therefore, energy is the capacity to change matter.

Everything we do involves energy. Getting up, going to school, and doing chores require energy. In fact, everything that happens in the universe, from the eruption of volcanoes, to the sprouting of seed, to the moving of people, takes energy. When we turn on a motor, drive a car, cook on a stove or switch on a light, we are using energy.

Energy surrounds us. It is everywhere and abundant, yet it has no **mass** and can't be touched. However, you can see and feel the effects energy has on many materials. Energy can produce motion, heat, or light.

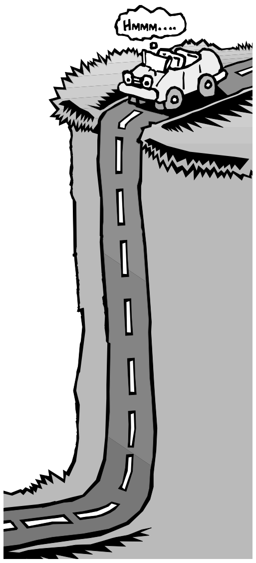
What Is Energy?

Two basic concepts are important in understanding the sources of energy:

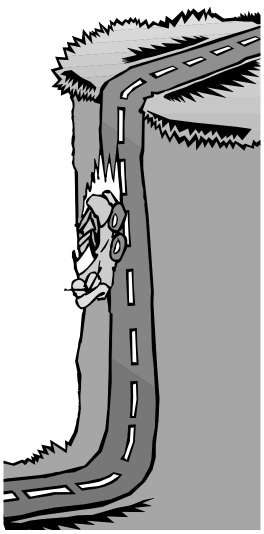
1. **Energy is the ability or capacity to do work.**
2. **Energy cannot be created or destroyed.**

Figure 1-1-1 What is energy?

Figure 1-1-2 *Everything that happens in the universe, from the sprouting of a seed to the eruption of volcanoes, involves energy.*



Car on the top of a hill– ***potential energy***



Car racing down a hill– ***kinetic energy***

▲
Figure 1-1-3 Examples of potential and kinetic energy

Energy cannot be created or destroyed. However, it can be changed from one form into another. Changing energy back and forth from one form or state to another is how we control it for our use.

Potential and Kinetic Energy

All energy can be in one of two states:

potential or **kinetic.**

Energy can be transferred from potential to kinetic and between objects.

Potential energy is stored energy—energy ready to go. A lawn mower filled with gasoline, a car on top of a hill, and students waiting to go home from school are all examples of potential energy. Water stored behind a dam at a hydroelectric plant has potential energy.

Gravitational potential energy is the energy possessed by a body because of its elevation (height) relative to a lower elevation, that is, the energy that could be obtained by letting it fall to a lower elevation. For example, water at the top of a waterfall or dam has gravitational potential energy.

Most of the energy under our control is in the form of potential energy. Potential energy can be viewed as motion waiting to happen. When the motion is needed, potential energy can be changed into one of the six forms of kinetic energy.

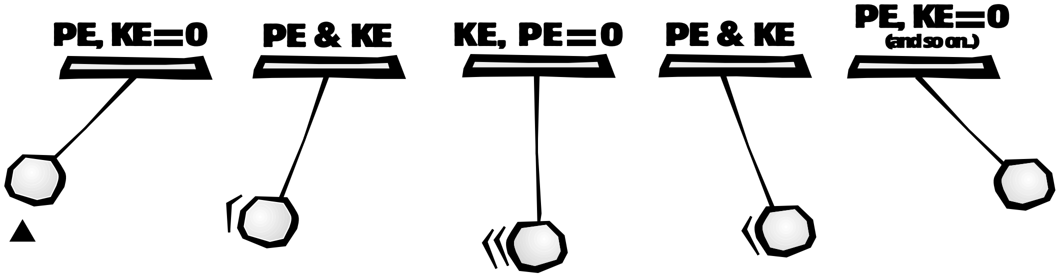


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Figure 1-1-4 Energy transfer in a pendulum
PE = Potential Energy ; KE = Kinetic Energy

Kinetic energy is energy at **work**. A lawn mower cutting grass, a car racing down a hill, and students running home from school are examples of kinetic energy. So is the light energy emitted by lamps. Even electrical energy is kinetic energy. Whenever we use energy to do work, it is in the kinetic state.

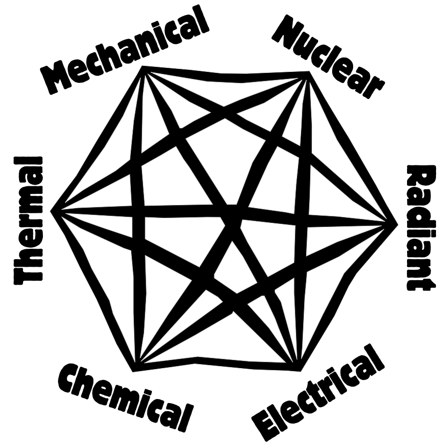


Figure 1-1-5 *Any of these forms of energy can be changed into any of the other forms.*

Forms of energy

Energy comes in six forms: **chemical**, **electrical**, **radiant**, **mechanical, nuclear** and **thermal**. These six forms of energy are all related. Each form can be converted or changed into any of the other forms. For example, when wood burns, its chemical energy changes into thermal (heat) energy and radiant (light) energy.

Not all energy conversions are as simple as burning wood. An automobile engine is a complex tool that converts the chemical energy in a fuel into mechanical energy, the energy of motion.

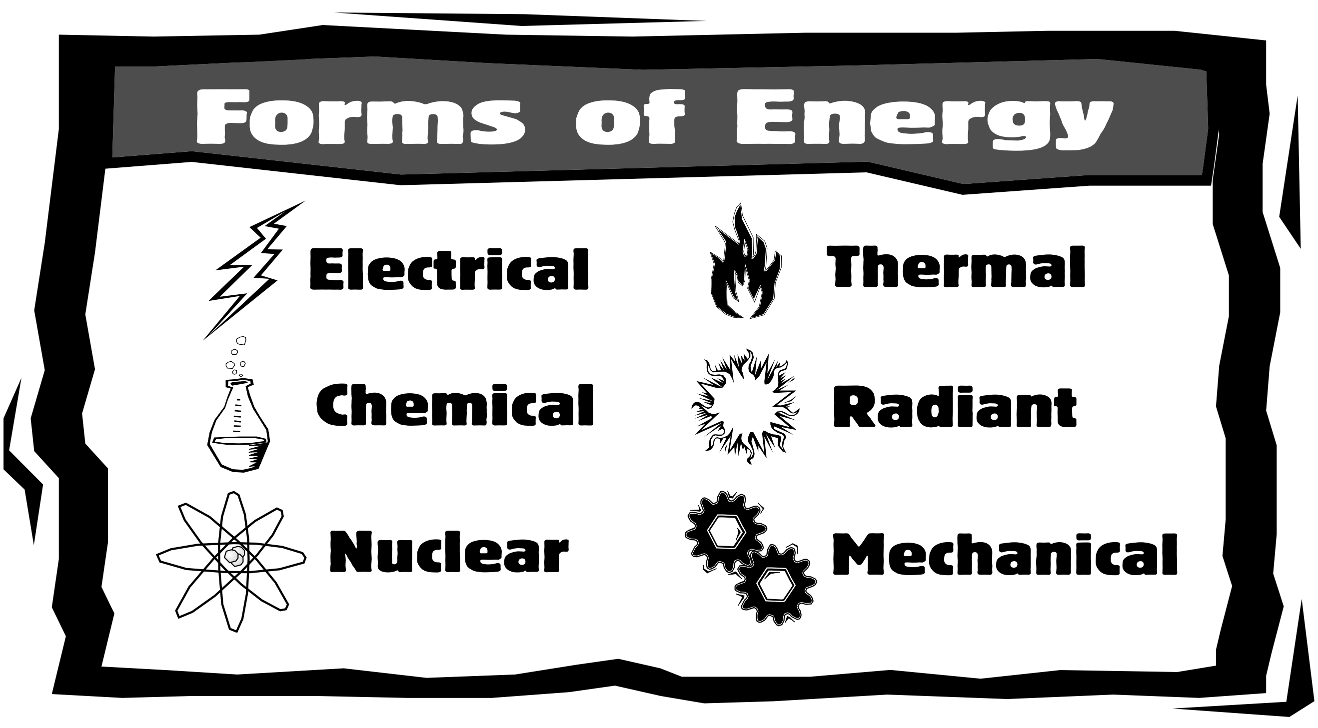
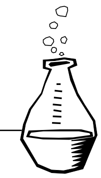


Figure 1-1-6 Forms of energy



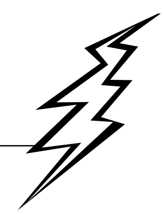
Chemical Energy

Energy stored in the bonds between **atoms** in molecules is chemical energy.
For example, in photosynthesis plants take in radiant energy from sunlight. This solar energy is stored in complex chemical **compounds** such as starches and sugars. The stored energy is released when these compounds break down into simpler compounds.

When you eat plant or animal tissue, your digestive system adds chemicals called enzymes that help break down the food. Digestion converts stored energy in food to other forms of energy that your body can use, such as mechanical energy to walk across the room.

Many energy sources commonly used by humans are forms of chemical energy. They are usually labeled "fuels." The way to use the chemical energy in most fuels is by burning them, as we do with wood, natural gas, gasoline, coal, and others. When these fuels burn, they give off heat, because the chemical reaction called combustion is an **exothermic reaction**—that is, it releases thermal energy in the form of heat.

Some chemicals contain a great deal of energy that can be released all at once. These chemicals are called explosives. For example, when dynamite explodes, its chemical energy changes very quickly into thermal and radiant energy and transfers from a potential state to a kinetic state.



Electrical Energy

Electrical energy is the energy carried by moving **electrons** in an electric conductor. It cannot be seen, but it is one of our most useful forms of energy because it is relatively easy to transmit and use.

All **matter** consists of atoms, and every atom contains one or more electrons, which are always moving. When electrons are forced along a path in a conducting substance such as a wire, the result is energy called **electricity**.

Electrical generating plants do not create energy. They change other forms of energy into electricity. For example, power plants can convert chemical energy stored in fuels into thermal energy, which evaporates water into steam, which produces mechanical energy as it moves through turbines. The turbines spin generators, which produce electricity.

Radiant Energy

Atoms absorb energy from an outside source and release (or "emit") this energy as **electromagnetic radiation**. This radiation can be in the form of waves of many different **wavelengths** or frequencies.

Visible light is electromagnetic energy emitted at wavelengths our eyes can see. Electromagnetic energy emitted at wavelengths we cannot see may take the form of **infrared radiation**, **ultraviolet radiation**, **X-rays**, **gamma rays**, and **radio waves**. Gamma rays have wavelengths much shorter than visible light. Radio waves are the opposite. Their frequencies are far longer than the longest waves our eyes can see (fig. 4-3-2).

Many energy sources emit radiant energy. The sun and other stars are luminous or "light-giving" objects that produce radiant energy from nuclear reactions. **Luminescence** may result from biological processes (e.g., fireflies), chemical reactions like burning kerosene in a lamp, **friction**, or electricity, as in a light bulb.

Mechanical Energy

Mechanical energy is the most familiar form of energy. It is the energy a substance or system has because of its motion. Every moving object has mechanical energy—whether it is a hammer driving a nail, a leaf falling from a tree, or a rocket flying in space. Mechanical energy pulls, pushes, twists, turns, and throws.

Machines use mechanical energy to do work. Our bodies also use mechanical energy to perform motions such as throwing a ball or moving a pencil to write on paper.

Nuclear Energy

A release of nuclear energy occurs when the nuclei of atoms are changed. **Hydrogen** and **uranium** are two kinds of matter used to produce nuclear energy. In a nuclear reaction, the tremendous binding energy inside a hydrogen or uranium nucleus is released.

Nuclear energy is released during atomic **fission**, when uranium nuclei are split. It is also released during **fusion**, when hydrogen nuclei combine to form a helium nucleus. In fission and fusion, nuclear energy produces thermal energy, which is given off as heat. Fission's heat is used to generate electric power in hundreds of locations worldwide. The sun and other stars use fusion to generate radiant and thermal energy. As stars give off energy, they lose mass. Someday, humans may be able to harness nuclear fusion as well.

Nuclear energy also has other uses. In medicine, it is used in radiation therapy to treat cancer. The U.S. Navy uses nuclear energy to power some submarines and large ships. They can stay at sea for long periods without stopping to refuel because their nuclear fuel takes up little space.

Thermal Energy

Thermal energy is the energy a substance or system has related to its temperature, i.e., the energy of moving or vibrating **molecules**. Atoms and molecules, the smallest particles of any substance, are always in motion. The motion of thermal energy is usually not visible, but we can feel or see its effects. We use thermal energy to cook our food and heat our homes, and we use it to generate electricity.

Thermal energy is not the same as heat. Heat is energy transferred between substances or systems due to a temperature difference between them. So it is correct to say that a system contains thermal energy, but not that it "contains" heat, since heat means energy that is transferred from one thing to another.

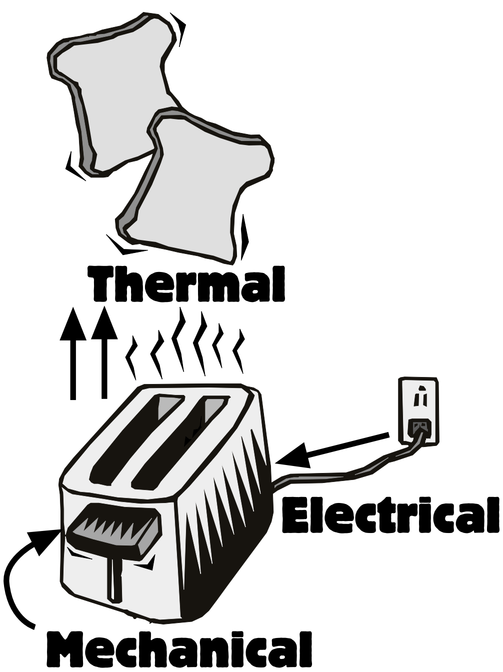


Figure 1-1-7 Energy transformation in a toaster

The amount of heat transferred by a substance depends on the speed and number of atoms or molecules in motion. The faster the atoms or molecules move, the higher the temperature, and the more atoms or molecules that are in motion, the greater the quantity of heat they transfer.

In solid substances, the particles' movement is limited, resembling vibration. Add heat to a solid, and the molecules move faster. When enough heat is added, the substance melts and becomes a liquid, in which the particles slip and slide past one another. Adding more heat eventually causes the molecules to bounce around randomly—the substance becomes a gas. These phase changes occur at different temperatures, depending on the substance.

Energy Transformations

Energy can be transformed from one form to another. For example, as water falls over a waterfall, its gravitational potential energy is first transformed into kinetic energy, then into thermal energy when it hits the ground. Or the kinetic energy of the water stream could be transformed (1) into the rotational kinetic energy of a turbine shaft, then (2) into electricity by turning the shaft of a generator, then (3) into thermal energy by passing the electricity through a resistor, raising its temperature. Finally, heat can be transferred from the resistor to the surrounding air, to warm a house.

The reason we transform energy from one form to another is because different end uses require different forms of energy. For example, sometimes we want electrical energy to power light bulbs that change electricity into electromagnetic radiation, some of which is visible as light. At other times we want the kinetic energy of a rotating shaft to provide mechanical energy to propel an automobile, so we transform chemical energy from fuel into thermal energy in a car engine, and then into the kinetic energy of the rotating crankshaft that provides power to turn the wheels.

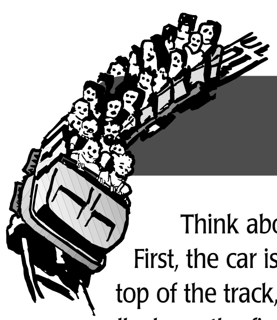
The Law of Conservation of Energy

The total amount of energy in a system remains constant, although energy can be changed from one form to another or transferred from one object to another.

Figure 1-1-8 The Law of Conservation of Energy

The Law of Conservation of Energy

We have often heard phrases like, "Conserve energy, turn off the lights." To scientists, conservation of energy is something entirely different. The **law of conservation of energy** states that the total amount of energy in a system remains constant ("is conserved"), although energy within the system can be changed from one form to another or transferred from one object to another.



Can Energy Disappear?

Think about the last time you rode a roller coaster. First, the car is pulled to the highest part of a track. At the top of the track, the car has potential energy. As the car rolls down the first steep slope, some of the potential energy changes into kinetic energy. At the bottom of the hill, all the potential energy has changed into kinetic energy.

When the car climbs to the top of the next hill, the kinetic energy changes back into potential energy. This process repeats itself throughout the ride. Normally, after the first hill the car moves without outside help. Each time it coasts down a hill it gains enough kinetic energy to climb the next one. However, some of the energy turns into heat in overcoming friction. For this reason, each hill in the ride is a little smaller than the one before it.

When scientists measure energy changes in a system such as a roller coaster, they find that when energy disappears in one form, an equal amount appears in another form. In other words, energy is neither created nor destroyed. It only changes form. This basic law of nature is called the law of conservation of energy.

Every energy control system has three parts:

1. *The original source of energy.*
2. *All the conversions the energy goes through, including the transmission (moving) of energy from one place to another.*
3. *The eventual use of the energy.*

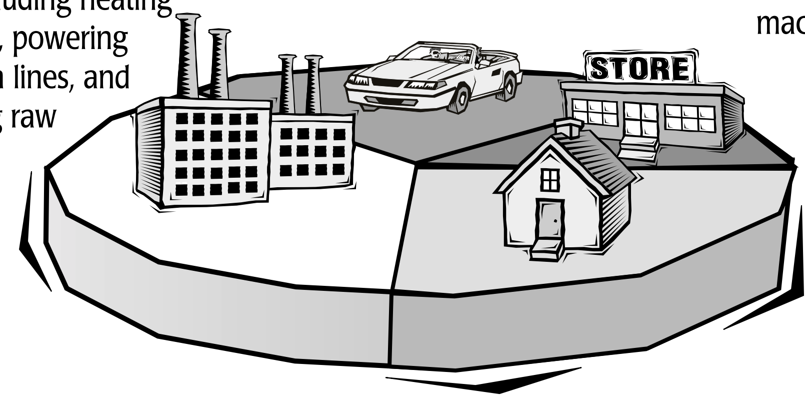
Figure 1-1-9 Energy control systems ▲

Energy cannot be created or destroyed, but it can be transformed. That's really what we mean when we say we are "using" energy. The law of conservation of energy means that when energy is being used, it is not being used up. Instead, it is being changed from one form into another. A car engine burns fuel, converting the fuel's chemical energy into mechanical energy to make the car move. Windmills change the wind's energy into mechanical energy to turn turbines, which then produce electricity. Solar cells change sunlight (radiant energy) into electrical energy.

Energy may change form many times on its way to doing work in your home, such as toasting bread *(see Figure 1-1-7)*. In the process, some energy is converted into unwanted thermal energy or waste heat. In fact, it is impossible to convert one form of energy into another without wasting some energy.

In many **energy conversions**, more energy is wasted than is used for work. For example, automobile engines typically waste more than two-thirds of the total energy used, primarily through heat.

Figure 1-1-10 U.S. energy consumption (1997) ▼



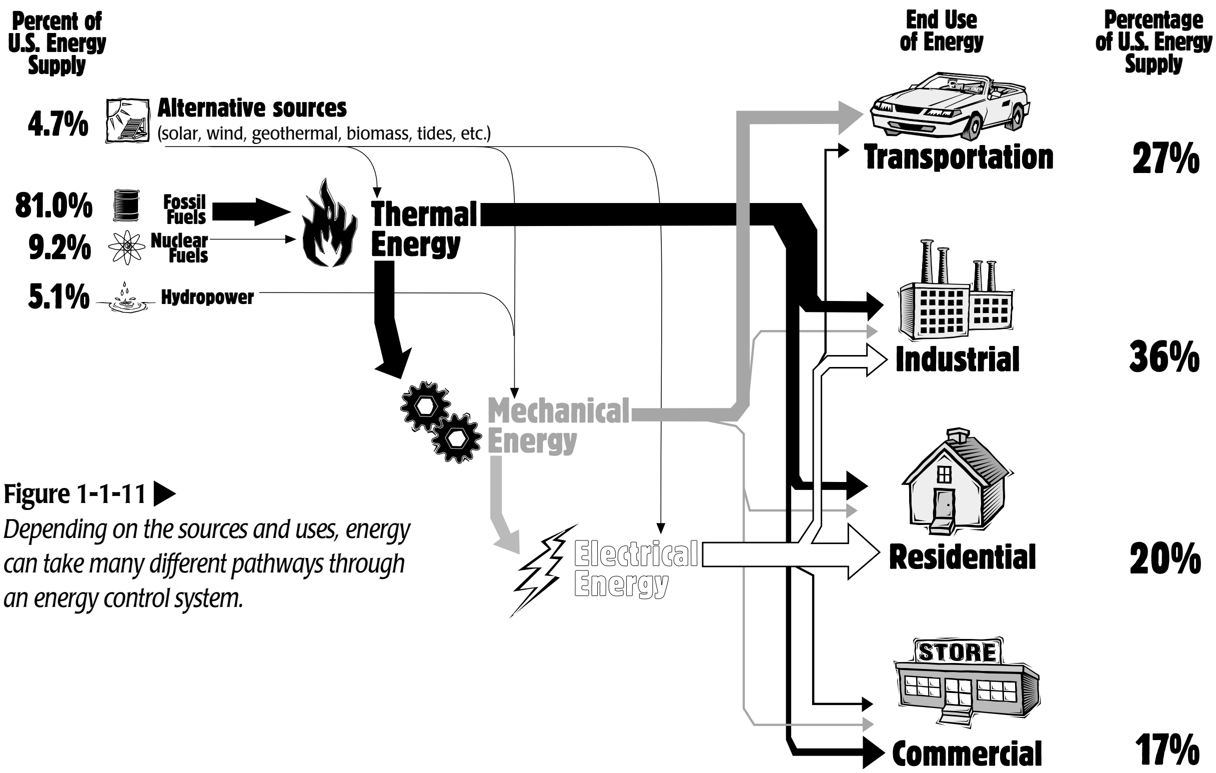


Figure 1-1-11 ▶
Depending on the sources and uses, energy can take many different pathways through an energy control system.

On the other hand, electrical motors convert electrical energy into mechanical energy with only about 10 percent of the energy wasted via heat. Energy efficiency means energy conversions from one form to another with as little waste of energy as possible.

Energy Control Systems

People have always looked for ways to control energy for their own use. For example, the steam engine allowed full control of a powerful energy source–expanding steam. People could control the direction, amount of power, and the duration of the energy output.

Since the invention of the steam engine, people have developed many new methods of controlling energy. We control energy for transportation, heating, and cooling.

Every energy control system has three parts:
1. The original source of energy.
2. All the conversions the energy goes through, including the transmission (moving) of energy from one place to another.
3. The eventual use of the energy.

One example of an energy control system is the generation, transmission, and use of electricity. The original source of energy is the fuel used at a generating plant—coal, for example.

From the source, the energy goes through the following conversions:

1. Chemical energy in coal is changed to thermal energy by burning.
2. Thermal energy boils water, which increases the speed of the molecules in the water and produces steam (mechanical energy).
3. Mechanical energy of the steam turns the blades in the turbine (mechanical energy), which generates electricity (electrical energy).

The electricity is then transmitted along power lines to where it is needed, such as in a home. There the electricity may be used to power motors, appliances such as radios and television sets, and provide light and heat.

Energeia Resource List

www.eia.doe.gov
Energy Information Administration, U. S. Department of Energy
Official energy statistics, an A-Z directory of energy information, and a "kids' page" with information on renewable and non-renewable energy.

www.doe.gov
U.S. Department of Energy
Main site for the agency; includes an online national library, energy glossary and database as well as energy lessons.